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The effects of water clarity on cichlid fish reproductive behavior

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INTRODUCTION:

- Humans are altering aquatic ecosystems in many ways, including increased turbidity, or the amount of sediments, in freshwater systems[1,2].
- Increasing turbidity can be problematic for fish like African cichlids, e.g. *Pseudocrenilabrus multicolor victoriae*, that rely on visual cues when choosing a mate[2,4,5].
- These fish come from a region of Uganda heavily reliant on agriculture, which increases turbidity in the surrounding waterways[3] (Fig. 1).

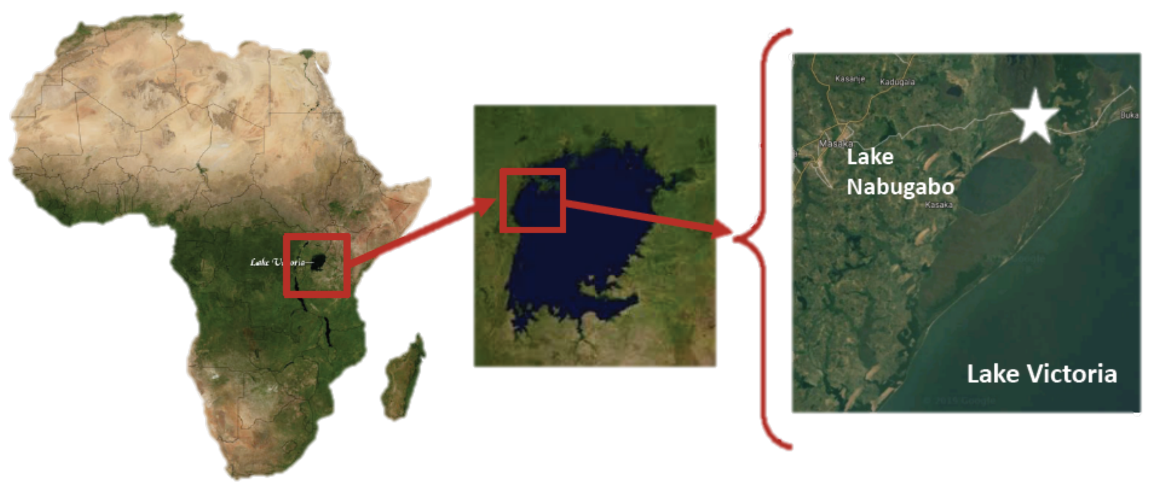

Figure 1. Lwamunda swamp (star) borders Lake Nabugabo, a satellite lake of Lake Victoria in Uganda, Africa.

OBJECTIVES:

- To determine if turbidity impacts male and female reproductive traits, such as female mate preference and male nuptial coloration (Fig. 2).
  - To test this objective, we used a dichotomous choice assay (Fig. 3).

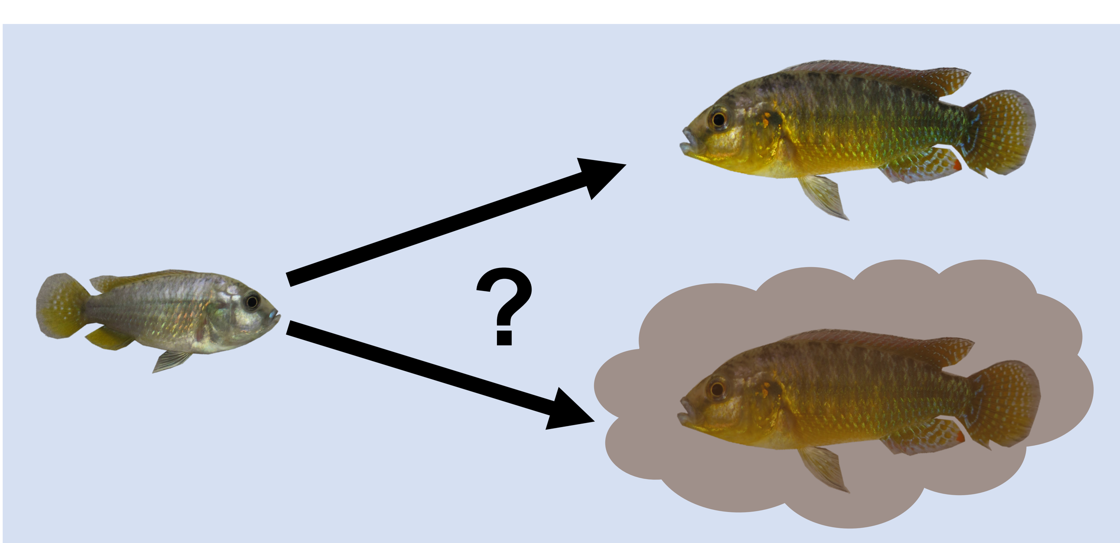

Figure 2. An increase in turbidity alters the visual environment and may affect visual cues for *P. multicolor* females (left) and males (right).

PREDICTIONS:

If turbidity affects the visual environment, then we expect male and female reproductive traits to differ in the following ways:

(a)females will be more active in clear experimental trials regardless of home rearing treatment;

(b) females will prefer males from their home rearing environment;

(c) male coloration will differ between rearing treatments.

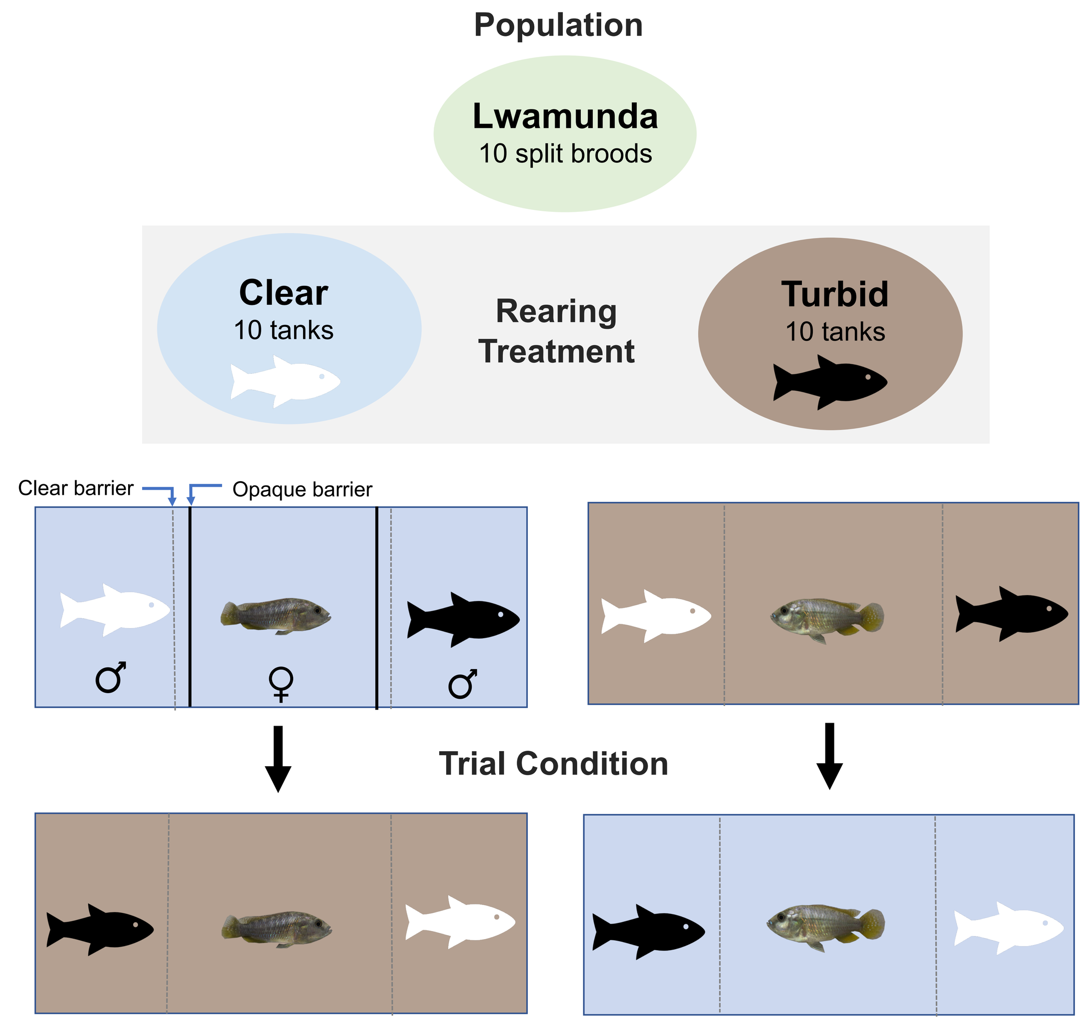

Figure 3. Tanks isolated a clear-reared and turbid-reared male on opposite ends, with a female in the center. Fish were acclimated overnight, with opaque barriers between compartments. The barriers were removed and behavior video-recorded for 30 min.

METHODS:

- Each female was tested with one pair of males under clear (0-0.5 NTU) and turbid (10-15 NTU) conditions, with trial order and male position randomized (Fig. 3).
- Female interactions were measured as the time spent interacting with males overall, and with each type of male.
- Preference was calculated as time spent interacting with clear males - turbid males (pos. value = clear male preference, neg. value = turbid male preference, 0= no preference).
- Photographs of males were taken post-trials and analyzed for color content (Fig. 4).
- We used repeated measures ANOVAs to test if rearing condition (clear or turbid) and treatment (clear or turbid trial; repeated) influenced reproductive traits.

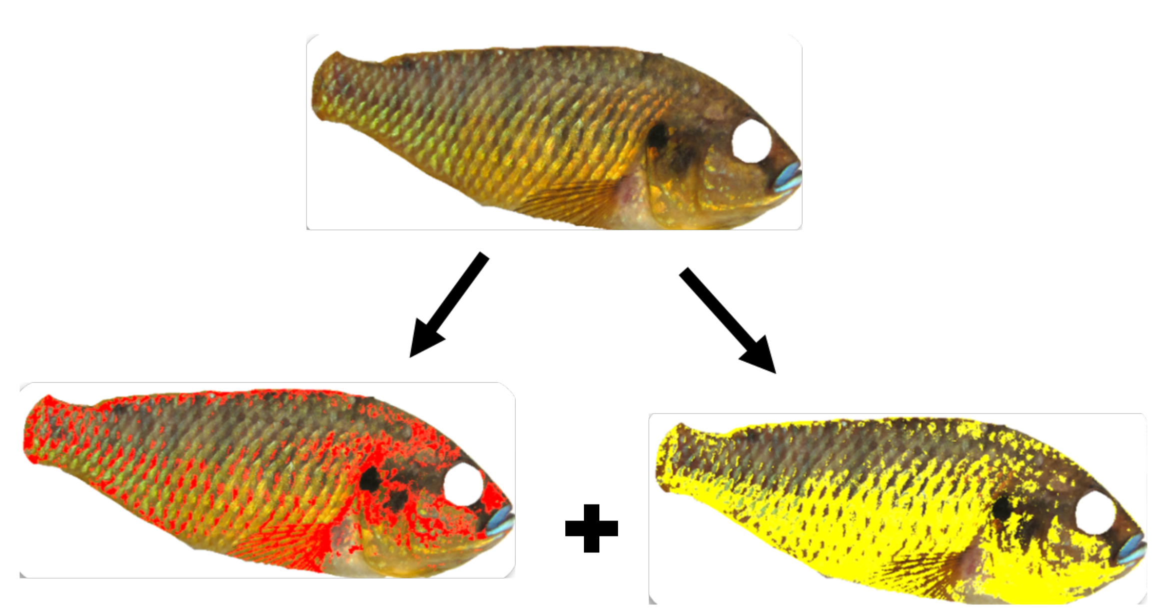

Figure 4: Photos were cropped and edited for white balance using Adobe Photoshop, then analyzed using an R package that calculates the total percentage of red (%red) and yellow (%yellow) pixels.

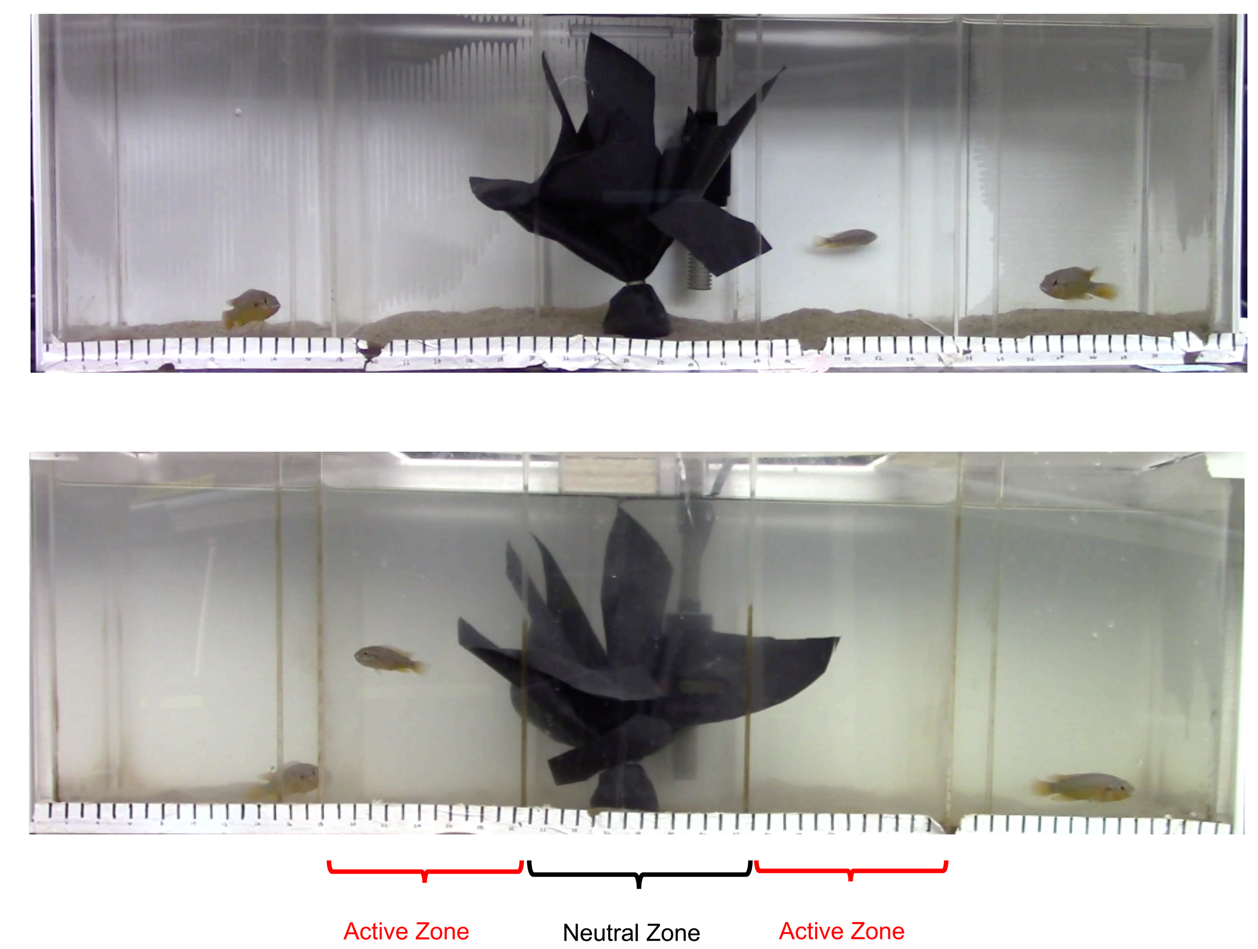

Figure 5. Clear experimental tank (top) at 0.31 NTU, and turbid experimental tank (bottom) at 15.4 NTU. Female interactions were measured as time spent interacting with each male within 12 cm of male (active zone).

RESULTS:

- Clear-reared females spent more time interacting with males in clear trials than in turbid trials; however, females reared in turbid water showed no difference in mating activity between clear and turbid trials (significant interaction $F_{1,10} = 23.04$, $P = 0.001$; Fig. 6).
- No significant difference was found in female preference of males from either rearing conditions under either trial type ($F_{1,10} = 1.894$, $P = 0.199$; Fig. 7).
- Male color content analyses showed no significant difference between rearing treatments ($t = 0.736$, $P = 0.474$, $df = 14$; Fig. 8).

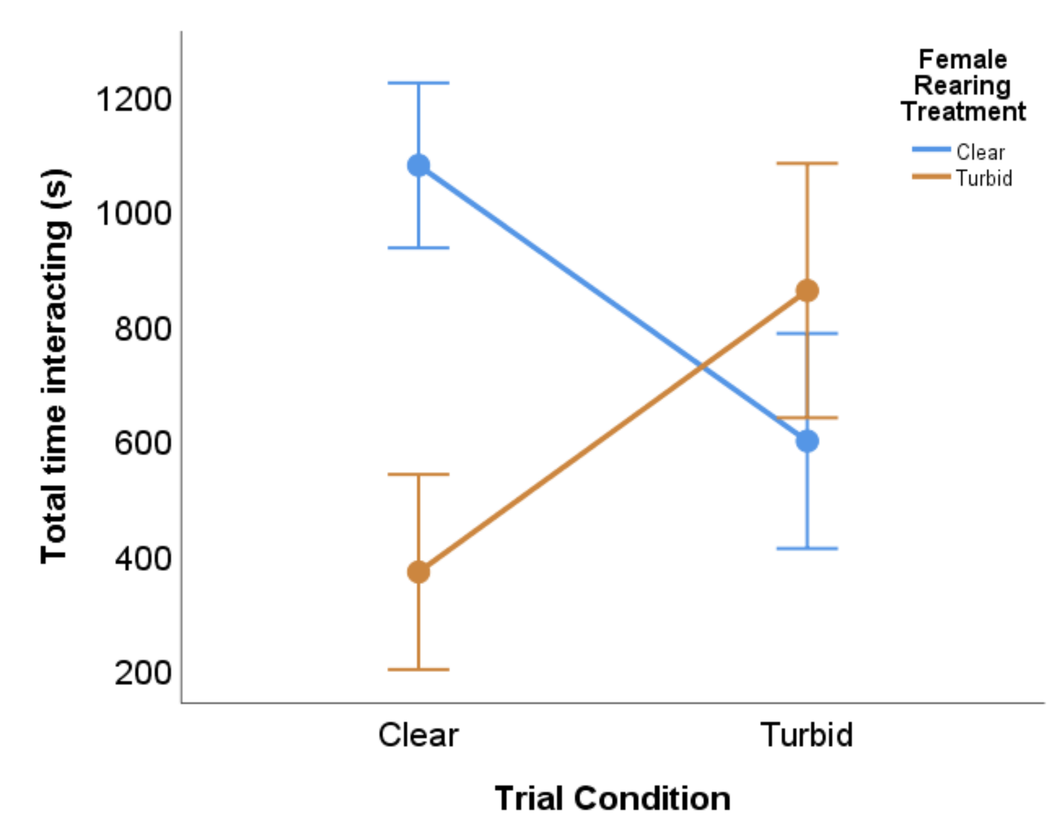

Figure 6. Clear-reared females spent significantly more time interacting with males in clear compared to turbid trials ($t_6 = 3.362$, $P = 0.015$) and the opposite was true for turbid reared females ($t_6 = -3.797$, $P = 0.019$).

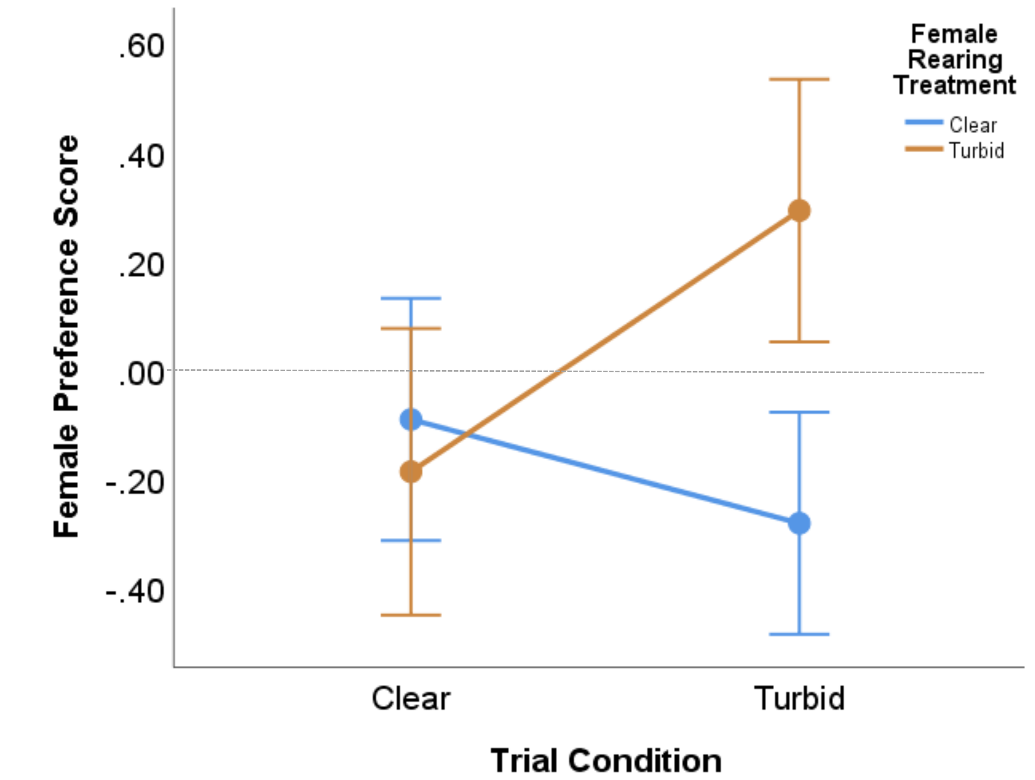

Figure 7. Mean female preference score (± s.e.) showing no significant difference in male preference between rearing or trial treatment (see methods for calculations).

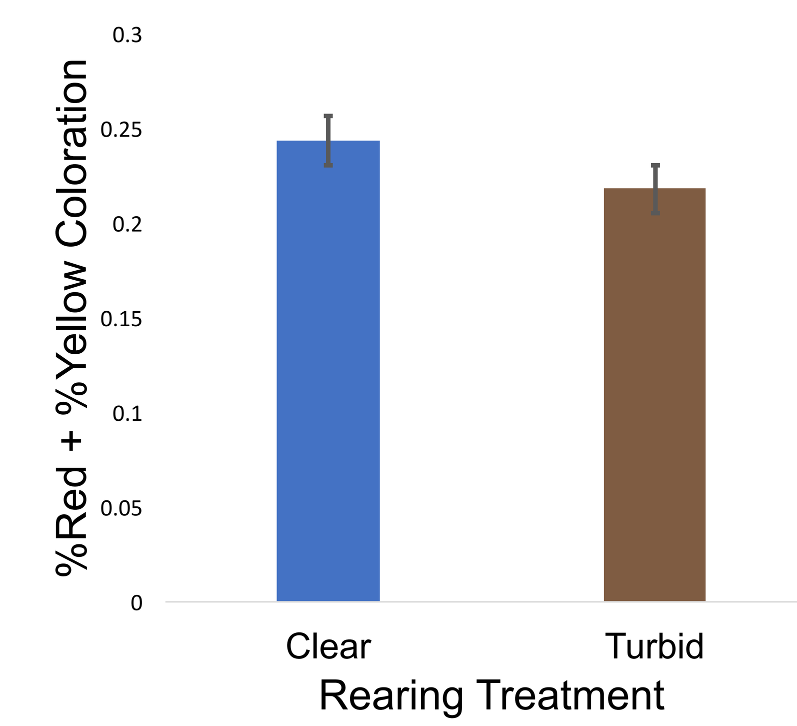

Figure 8. Clear and turbid-reared males average % yellow + % red pixels (± s.e.) showing no significant difference in male coloration between rearing treatments.

DISCUSSION:

- Fish not accustomed to turbid water (i.e. clear-reared females) may spend less time engaging in reproductive behaviors, potentially indicating that turbidity will decrease reproduction, resulting in biodiversity loss.
- A lack of color variation between males reared under different treatments may suggest that color expression was not influenced by turbidity in this population that comes from a clear swamp (i.e. color is not plastic).
- We did not find evidence for female mate preference, which could be a result of no significant difference in color between male rearing conditions.

LITERATURE CITED

1.Gray et al 2011. Ecology of Freshwater Fish. 20:529-536; 2. Reid et al 2018. Biological Reviews. 94(3): 849-873; 3. Gray et al. 2012. Current Zoology 58:146-157; 4. Candolin 2019. Biological Reviews 94(4):1246-1260; 5. Seehausen et al. 1997. Science. 277(5333): 1808-1811.

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